TEACHING DEMONSTRATION WITH A CLASS

By Mr. Burton L. Cushing

Mr. Burton L. Cushing, Head of the Science Dep't. at the East Boston High School and Special Lecturer in The Teaching of Physics at the Harvard Graduate School of Education gave a teaching demonstration with a class of 12 boys from the Milton Academy and the Milton High School. The subject of Heat was introduced with the topic of Temperature and Expansion. The class had not had the subject before in their own classes. First the boys answered some introductory questions at the beginning of the Chapter on Temperature and Expansion in Stewart, Cushing and Towne's *Physics for Secondary Schools.* Then answers showed that the boys had some general ideas about the subject but did not really understand it in a technical or scientific sense. Then the teacher presented demonstrations showing the expansion of solids, liquids, and gases, at the same time asking questions of the class to get them to explain and discuss what they saw, and also to get them to give practical examples of the principles being illustrated. He added enough information to that volunteered by the boys so that at the end of the class the principle had been well enough taught so that the pupils should be able to understand the home lesson assignment for the next day which was pp. 207–216 with the 7 problems on p. 213 in the above mentioned text.

The principles of teaching brought out by the demonstration were: first, the use of introductory questions to stimulate interest; second, presenting the topic in class before an assignment had been given from the text; third, an experimental demonstration as an introduction to a new topic; fourth, participation of the class in developing the principle; and fifth a text book assignment as a means of fixing the principle and its applications in the minds of the pupils.

The presentation was well received by the members present which indicates that a repetition of this experiment by some other members of the association at a later meeting might be profitable.

The members of the Association were guests of Milton Academy at luncheon. After a social hour they were greeted by Mr. W. L. W. Field, Headmaster of Milton Academy. He gave an interesting account of Mr. Lee, the founder of the study of physics there forty-five years ago, of his work, and the tradition he established and which still lives. He ended his talk with the advice to maintain the simple quiet attitude of inquiry, and to avoid the mystifying or conjurors attitude.

SCIENCE IN EDUCATION, FROM THE VIEWPOINT OF BENJAMIN FRANKLIN

Address by Dr. Karl T. Compton, *President of the Massachusetts Institute of Technology*

It occurred to me, in accepting your invitation this afternoon, that it might be interesting and appropriate to discuss some aspects of Benjamin Franklin's philosophy of education, as I recently had occasion to review them in connection with the sesqui-centennial of Franklin and Marshall College this Fall. For Franklin was America's first great scientist; he was a product of New England; his originality, ingenuity and sound common sense give him a unique position in the history of American science.

No statement, to my way of thinking, could be more expressive of Benjamin Franklin's philosophy of education than that which is taken from the petition that originally requested the granting of a charter for the establishment of Franklin and Marshall College. This petition expressed "conviction of the necessity of diffusing knowledge through every part of the state, in order to preserve our present republican system of government, as well as to promote those improvements in the arts and sciences which alone render nations respectable, great and happy."

Just as a preacher commonly uses a text, either as an authority for something which he wants to say, or to suggest to his mind some line of thought that may be explored with profit to his hearers, so it occurred to me that I might discover among the numerous writings of Benjamin Franklin some suitable basis for my remarks. Explaining this to our librarian, I asked him to send me a couple of good books on Franklin's life and writings. He sent me six large books which I read with fascination and profit, but in none of them could I find any explicit statement by Franklin on the social values of science or on the rôle of science in education.

This dearth of statements about science in education on the part of one who had such an absorbing and productive interest in science and who was so fond of giving advice and recipes on the subject of self-improvement, was a decided surprise to me. It is evident, however, that Franklin's interest in science was *in science* and not in talking or philosophizing about it. And here is a very important point: To Franklin, interest in science seemed so natural that he felt no need to argue it; its practical use was so apparent that he did not have to defend it. He simply did his scientific work and the results themselves were the most eloquent demonstration of its import.

The only clues which my reading gave me regarding Franklin's ideas about science in a school curriculum were of an indirect nature. For example, he did not approve of the teaching of Latin or Greek,—not because he disapproved of them per se, but because he believed the time could be spent to better educational advantage on other subjects. When, in 1743, he drafted a plan for establishing an academy in Philadelphia,—later to become the University of Pennsylvania,—he described "a house in a high and dry situation, not far from a river, having a garden, orchard, meadow and a field or two, a library and an equipment of scientific apparatus; the scholars were to live plainly and temperately, and to be frequently exercised in running, leaping, wrestling and swimming. As to their studies, it would be well if they were taught *everything* that is useful and *everything* that is ornamental. But art is long and their time is short. It is therefore proposed that they learn those things that are likely to be *most* useful and *most* ornamental, regard being had for the several professions for which they are intended." At this time Franklin urged no one special feature of the curriculum except that it should give training in the use of the English language. But all through his connection with the academy, he struggled

to prevent his "useful" studies from being stifled by the weight and prestige of the classical studies. In this connection he wrote:

"There is in mankind an unaccountable prejudice in favor of ancient customs and habitudes, which inclines to a continuance of them after the circumstances which formerly made them useful cease to exist. A multitude of instances might be given, but it may suffice to mention one. Hats were once thought a useful part of dress; they kept the head warm and screened it from the violent impressions of the sun's rays, and from the rain, snow, hail, etc.

"Gradually, however, as the wearing of wigs and hair nicely dressed prevailed, the putting on of hats was disused by genteel people, lest the curious arrangements of the curls and powdering should be disordered, and umbrellas began to supply their place; yet still our considering the hat as a part of the dress continues so far to prevail that a man of fashion is not thought dressed without having one, or something like one, about him, which he carries (chapeau bras, which means) under his arm. So that there are a multitude of the politer people in all the courts in capital cities of Europe who have never, nor their fathers before them, worn a hat otherwise than as a chapeau bras, though the utility of such a mode of wearing is by no means apparent, and is attended not only with some expense but with a degree of constant trouble.

"The still prevailing custom of having schools for teaching generally our children in these days the Latin and Greek languages I consider therefore in no other light than as the chapeau bras of modern literature."

Franklin had no patience with the practice of sending children to college for social prestige rather than intellectual endeavor, and I suspect that he would, today, advocate rigid entrance requirements, and at the same time would desire colleges of many types to educate different groups for the various objectives which have a proper place in our social order. In reference to high standards Franklin deplored the tendency of "every Peasant, who had the wherewithal, to send one of his children to this famous Place (a college) in which, as most of them consulted their own purses instead of their Children's Capacities, I observed a great many, yea the most part of those who were travelling thither, were little better than Dunces and Blockheads. Many of them from henceforth for want of Patrimony, lived as poor as Church Mice, being unable to dig, ashamed to beg, and to live by their wits was impossible."

So we learn something of Franklin's educational philosophy: he included science among the studies "most useful and most ornamental"; it is evident that he put science alongside of citizenship as the socially most important objectives of the college training; he emphasized the importance of acquiring ability to use effectively the English language; he felt that the dead languages were relatively overemphasized in the schools of his day; and he deplored the wasting of educational facilities upon students of inferior quality.

But, while we learn little about Franklin's ideas of science in education from Franklin's writings, we learn a great deal from his actions. He had a burning curiosity to know the facts and explanations of his environment. He was never so happy as when studying or experimenting on scientific questions. He had an irrepressible urge to turn his scientific knowledge to practical account through inventions. He was so impressed with the social values of these inventions that he refused to accept any financial reward from them, but donated them freely to the public. Franklin's interest in science was, therefore, very direct and very practical.

Perhaps the most comprehensive statement which Franklin made to indicate his range of interests in science and his faith in its practical value to mankind, is found in his plan of 1743 for founding the American Philosophical Society. As I read the following quotation from his prospectus of this society, I would ask you to note that today, nearly 200 years later the same subjects are matters of intense interest in science, industry and agriculture. He specified:

"That the subjects of correspondence be: all new discovered plants, herbs, trees, roots, their virtues, uses, etc.; methods of propagating them, and making such as are useful, but particular to some plantations, more general; improvements of vegetable juices, as ciders, wines, etc.; new methods of curing and preventing diseases; all new-discovered fossils in different countries, as mines, minerals and quarries; new and useful improvements in any branch of mathematics; new discoveries in chemistry, such as improvements in distillation, brewing and assaying of ores; new mechanical inventions for saving labour, as mills and carriages, and for raising and conveying of water, draining of meadows, etc.; all new arts in trades and manufactures—and all philosophical experiments that let light into the nature of things, tend to increase the power of man over matter and multiply the conveniences or pleasures of life."

Not only is this outline of the scope of science as applicable today as it was when Franklin wrote it, but the field appears to be inexhaustible. As he himself said, "The world is daily increasing in experimental knowledge, and let no man flatter the age with pretending that we have arrived at a perfection of our discoveries."

With this perspective of the scope and practical value of science, expressed in Franklin's own words, I would suggest four educational values of science which, severally and together, justify science as an important part of any school curriculum and point the objectives toward which the educational processes should be directed.

(1) First in importance I should put advancement of knowledge. This involves research in the higher stages and study in all stages of education.

But to extol knowledge without exercise of critical judgment as to the relative values of different kinds of knowledge is folly. For, while we admit that all knowledge is desirable, as contrasted with ignorance, yet some categories of knowledge are so much less significant than others, that their pursuit may be the height of foolishness. To know, for example, the num-

bers of times in which each letter of the alphabet occurs in the King James version of the Bible is, except perhaps for a printer, of far less significance than to know the problems confronting our legislatures or the basic principles of electricity.

While Franklin did not limit his interest in science to what was immediately useful, it is evident that he had a profound conviction that accurate knowledge of Nature and of Man, based on observation and experimentation, stood very high in the scale of relative values of knowledge.

Scientific knowledge has had enormous influence on man's cultural and spiritual development,—in his attitude toward his relation to his environment. It has replaced ignorant superstition, in which men could be swayed by fears, with that security and confidence that arise from understanding. "The truth has set men free."

Even in Franklin's time superstitions were rife. When he invented the lightning rod, for protection against the dangers of lightning, and when lightning rods were being installed on many buildings, Franklin and his inventions were vigorously assailed by the clergy as sacrilegious and tempting the wrath of God. For, argued they, was not lightning an instrument of punishment and admonishment in the hands of God,—especially when skilfully dealt upon in their sermons for the purpose of inciting the fear of God in their congregations? These attacks on Franklin lasted for years. In a period of earthquakes in New England, the ministers were not slow to infer this evidence of God's wrath at having his lightning tamed by Franklin's rods.

But not only in the negative field of freeing men from superstitions and fears, whether attached to religions or otherwise, has scientific knowledge helped mankind spiritually: it has had the positive value of orienting him in his environment and showing him, in this environment, the marvelous order and coördination which pervades the infinite complexities of the world. In this way, science has a powerful cultural influence, if we are willing to accept the definition of culture as "sympathetic understanding and appreciation of life."

Life has various aspects, emotional and intellectual. Music hath charms to soothe the savage breast. In literature we have access to the finest thoughts and feelings of mankind. All of these, and religion, have power to bring us a mystical uplift of feeling. All contribute to true culture. Likewise does science. It too expresses symmetry of form and relationship. It too requires imagination. It too interprets life. But in addition it possesses a power and exercises a type of discipline which is unique.

So I would place the advancement of knowledge through science as the most important contribution of science in education, and I would place first the cultural rather than the utilitarian values of this knowledge.

(2) Equal in importance, I would put the intellectual disciplinary value of scientific study and investigation. Franklin himself expressed this very clearly. Replying to a criticism of his theory of waterspouts, he wrote:

"Nothing certainly can be more improving to a Searcher into Nature,

than Objections judiciously made to his Opinions, taken up perhaps too hastily: For such Objections oblige him to restudy the Point, consider every Circumstance carefully, compare Facts, make Experiments, weigh Arguments, and be slow in drawing Conclusions. And hence a sure Advantage results; for he either confirms a Truth, before too lightly supported; or discovers an Error, and receives Instruction from the Objector. In this View I consider the Objections and Remarks you sent me, and thank you for them sincerely."

He describes the true scientific spirit as follows: "I was too easily led into that error by accounts given even in the philosophical books. . . . But men are, in general, such careless observers, that a philosopher cannot be too much on his guard in crediting their relations of things extraordinary, and should never build an hypothesis on anything but clear facts and experiments, or it will be in danger of soon falling . . . like a house of cards."

When some of his electrical experiments led him to distrust some earlier conclusions, he wrote: "If there is no other use discovered of Electricity, this however is something considerable, that it may help to make a vain man humble."

I have always believed that training as a scientist implants in the student certain habits of careful and logical thought that tend to protect him against irrational or emotional action and to improve his judgment and administrative procedures. If this be true, then a strenuous course in science would be good training not only for a future scientist, but also for a future business man or public official. By way of illustration, consider Franklin's description of a Striking Sundial, which reads:

"How to make a Striking Sundial by which not only a man's own family, but all his neighbors for ten miles round, may know what o'clock it is, when the sun shines, without seeing the dial.

"Chuse an open place in your yard or garden, on which the sun may shine all day without any impediment from trees or buildings. On the ground, make out your hour lines . . . taking room enough for the guns. On the line for one o'clock, place one gun; on the two o'clock line two guns, and so of the rest. The guns may all be charged with powder, but ball is unnecessary. Your . . . style must have twelve burning glasses annexed to it, and be so arranged that the sun shining through the glasses, one after the other, shall cause the focus or burning spot to fall on the hour line of one, for example, at one o'clock, and there kindle a train of gunpowder that shall fire one gun. At two o'clock, a focus shall fall on the hour line of two, and kindle another train that shall discharge two guns successively; and so of the rest.

"Note, there must be 78 guns in all. Thirty-two pounders will be best for this use; but 18 pounders may do, and will cost less, as well as use less powder.

"Note also, that the chief expense will be the powder, for the cannons once bought will, with care, last 100 years.

"Note, moreover, that there will be a great saving of powder in cloudy days.

"Kind reader, methinks I hear thee say, that is indeed a good thing to know how the time passes, but this kind of dial, notwithstanding the above mentioned savings, would be very expensive, and the cost greater than the advantage. Thou art wise, my friend, to be so considerate beforehand; some fools would not have found out so much, till they had made the dial and try'd it. . . . Let all such learn that many a private and many a publick project, are like this striking dial, great cost for little profit."

(3) The third educational value of science is its practical utility. Perhaps the practical minded Franklin would have placed this first. Most, though not all, of his scientific work was either stimulated by his desire to accomplish some useful end, or else had a utilitarian by-product. His extensive studies of the flow of air through pipes and past orifices was stimulated by his desire to design a more efficient stove and a convenient system of ventilation. His invention of bifocal spectacles sprang from his own needs. His construction of a naval towing tank, and experiments on the water resistance to the motion of boat models, were stimulated by his interest in promoting canal transportation.

On the other hand his invention of the lightning rod, and of an electrical method of slaughtering poultry and animals so that their meat would be more tender when eaten, were by-products of a long series of investigations on the nature of electricity and of electrical phenomena which he undertook primarily out of pure scientific curiosity and love of experimental research. Similarly his identification and explanation of lead poisoning, his charting of paths of navigation on the Atlantic Ocean to take best advantage of the Gulf Stream and the Trade Winds, his discovery of marsh gas, and his method of calming stormy water by pouring oil on it, all these were the practical by-products of observations and studies which were certainly not undertaken in the beginning with any immediate practical purpose in view.

The practical value of science is no less real today than in Franklin's day; if anything it has been accentuated by such factors as increasing competition and the necessity of using and conserving our natural resources more wisely. Consider the great problems before our nation today, and you will see that many of them are inherently dependent on science for solution. To be sure many issues are political, like the Supreme Court, or the Civil Service, or labor relations; others are financial, like reciprocal tariffs, taxes and stock market regulations. But there is a great group of problems such as employment; hours and wages of labor; conservation and utilization of national resources; protection against hazards of flood, fire, earthquake, wind and drought; development of new uses for farm products; housing; health; and many others, all of which are fundamentally dependent on science for solution.

It is important, for the welfare of the country, that our colleges prepare young men and women with a training in science which will make them

competent to contribute effectively to the solution of these problems. It is equally important that the rank and file of our population, and especially our future political leaders, be given a sufficient understanding of science to enable them to appreciate what science can do and what conditions are prerequisite to its effective operation.

In this altogether inadequate fashion, I have tried to express certain thoughts on science and on education, and to cast these thoughts against the background of our first great American scientist, Benjamin Franklin. Science has a valuable part in education, because it creates knowledge, disciplines the mind and has great utility. You may study it from a sense of duty, because of these three values, or you may study it for fun. I suspect the latter is the real motive power and the former is the excuse behind most real scientists. But, however it is viewed, science seems destined to occupy an increasingly significant place in our educational system. Through it, some will be enabled to add directly to our understanding of the world and our comfort in living. Its students will be better trained to view situations objectively, to draw rational conclusions from observed facts, to plan an intelligent course in the light of these facts and conclusions, and thereby to be safer citizens in our self-regulating society—our democracy.

RESEARCH AT LOW TEMPERATURES

Address by Dr. Harold T. Gerry

The use of low temperatures should not be considered particularly as a field of research in itself but rather as a very valuable tool in tackling many a problem in varied fields of research. It is from this point of view that we in the low temperature laboratory at the Massachusetts Institute of Technology have been spending a large fraction of our time in the last few years in considering the processes of refrigeration. We have been attempting to simplify the production and maintenance of low temperatures in such a manner that any reasonably well financed research laboratory may install facilities for work at low temperatures, if such facilities are advantageous in making further progress on problems already under study.

We might consider briefly a few of the points that make low temperatures useful in a variety of types of research.

Many of the predictions of modern quantum theory and atomic structure can be most satisfactorily checked experimentally at low temperatures. Higher temperature data can often be treated with reasonable accuracy by very simplified theories. At low temperatures, however, these simplified theories will fall down completely, and a good test of the more complicated theory may be made. Consider such a simple phenomenon as coefficient of expansion of a metal. The coefficient of expansion is almost independent of temperature at around room temperature but suddenly starts dropping rapidly somewhat below the ice point and is almost zero by the time one reaches the boiling point of liquid hydrogen.